Conceptualization of the optimal design of a hydroxyl booster dry cell for enhancing efficiency of internal combustion engines

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Abstract

Current internal combustion engines (ICEs) are powered by fossil fuels which create the challenges of low combustion efficiency and the emission of greenhouse gases. This has negatively affected the environment, leading to global warming and climate change. Interim technologies can be implemented to reduce these effects whilst alternative technologies are being explored. This research aimed at selecting the most appropriate geometrical design of a hydroxyl booster dry cell, a device which operates on the principles of electrolysis to produce hydroxyl gas commonly referred to as Brown gas or HHO. When a voltage is applied to a body of water, it splits it into its base components, i.e. hydrogen and oxygen cold plasma, a mixture sometimes referred to as hydroxyl gas. The addition of hydroxyl gas into the combustion chamber of an ICE initiates a more complete combustion due to the explosive and diffusive nature of hydrogen accompanied by the cooling effect of water thus reducing potential for NOx formation. This leads to fuel savings, cost savings and reduced emissions. A rectangular hydroxyl booster dry cell was selected and designed, fabricated and tested for effectiveness. The HHO generator is later connected to the ICE system to check mainly on the positive contributions of this Brown's gas as HHO is popularly known.

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Keywords: Dry cell; hydroxyl; internal combusion

1. Introduction

Greenhouse gases emitted from the combustion of fossil fuels are causing global warming, erratic rainfall patterns and if their sources continue unabated it may become difficult to sustain life on planet earth. This research is meant to minimize emitting harmful byproducts of combustion into the atmosphere [11]. Given these precarious situations, one would expect internal combustion engines to be highly efficient [13]. However, such is not the case as internal combustion engines have a low thermal efficiency, averaging slightly above 20% [19]. This is due to the incomplete combustion of gasoline in the engine caused by the limited time the air/fuel mixture is in the combustion chambers, and also the slow flame speed which ranges from 0.2 to 0.9 cm/min [7]. The heat balance sheet of the gasoline powered ICE shows that the brake load efficiency falls between 21 to 28%, loss to cooling water is between 12 to 27%, loss to exhaust is between 30 to 55 %, and loss due to incomplete combustion can be as high as 45% [9]. Hydrogen injection has been found to be a much more effective way of increasing the thermal efficiency [14] but the problem is on handling the deadly gas [6]. Hence HHO booster cells, both wet and dry designs, have been developed over the past decade by mechanics and technology enthusiasts for on-demand supply of HHO]. The mixture of gasoline and hydroxyl gas, is fed through a single duct into the engine in which it instigates a more complete combustion of the gasoline [2,15].

2. Materials and methods

Three different designs of HHO generators were used in the study and the one that produced the best results was taken up for further development [5]. There are problems due to heat production caused by current flowing through the plates. The cell's designs need to be optimized in various ways and this research is mainly focusing on optimum geometrical design. There is also production of foam and steam which are released along with the HHO gas. In order to select the booster cell, experiments and variation of design parameters had to be instituted to determine the plausible design [4]. Parameters that will be considered are shape of the plates, material of the plates, electrolyte solution [10,11], configuration of conducting plates and number of plates. In addition to this, a cooling mechanism was to be determined for the HHO booster dry cell based on the coefficient of conductivity of the plates' parent material. A concept selection method in a matrix format was used using varying parameters such as Safety, Cost of material, Ergonomics, Weight Ease of manufacture e.tc.

After the cell has been chosen it was put on a test to verify that HHO when applied to gasoline operated internal combustion engines will improve combustion efficiency. The combustion efficiency [1,8] improvement was depicted on a Load against either speed, Break Power, Indicated Power, Indicated Specific Fuel Consumption and Thermal Efficiency graphs. For this research results for only the results for Load against Brake and Load against Thermal Efficiency are given to illustrate the improvement in operating efficiency of the internal combustion engine. Fig 2.1 below shows the schematic of the HHO connection to the ICE engine system.

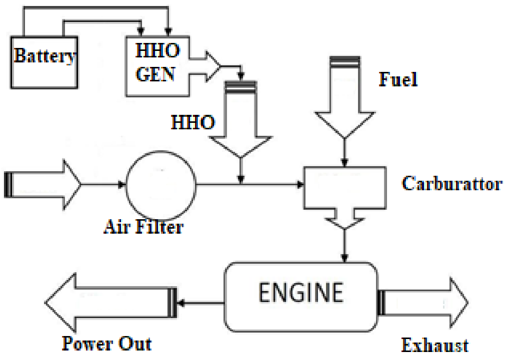

Fig. 2.1 Block diagram for HHO gas production

3. Background and selection of HHO generator concept

3.1 The comparison of the three most likely HHO generator solutions

Fig.3.1 is an illustration of the three HHO generator cells' geometrical designs from which the best option was chosen. For the first concept, the rectangular dry cell is made up of stainless steel grade 316L plates which are 150mm by 150mm by 3mm thick. The gasket material is soft clear PVC sheeting and the fastening bolts are made of stainless steel. The orientation of the cell is horizontal and there are holes in the plates for refilling the cell. Advantages of this dry cell are: It is compact and therefore can be connected easily to a vehicle. The cell is easier to refill because of the holes drilled through the plates. The disadvantages are: The holes reduce the efficiency of the cell because of current leakage and the cell cannot be run for a long duration because it heats up after approximately 2 hours. Concept number 2 is the Diamond shaped shell that reduces the area which is not utilized for electrolysis. The area in which no electrolyte is present is of not used in the production of HHO gas and actually leads to an increase in the operating temperature of the cell. Electroplated platinum is used which conducts electricity very well and does not react with hydrogen. electroplating is a more sustainable process compared to using a solid plate of platinum on cost basis [12].

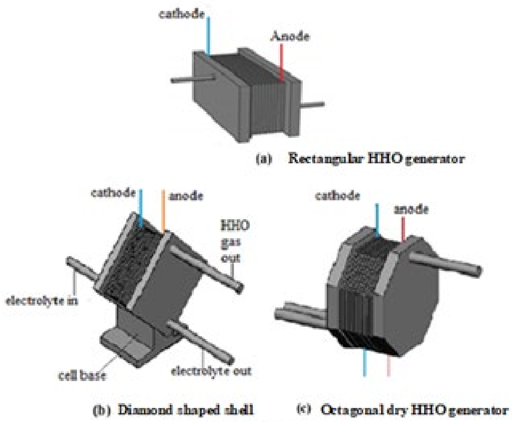

Fig . 3.1. HHO generator concepts

Concept 3 is the Octagonal dry HHO generator configuration which improves efficiency of the cell compared to the first concept. High surface area utilization for electrolysis leads to high HHO production. The diamond cooling concept makes use of a fan to provide cool air which flows over the cell. Advantages of Diamond shaped concept are that it utilizes more surface area for improved efficiency Tungsten does not release harmful chemicals. Disadvantages of Diamond shaped concept are that the more preferred Tungsten metal for plate making is not readily available. The diamond shape requires a cell base for the dry cell to be balanced, which increases costs. The shape of the plates requires advanced machining to duplicate them and the cooling system drains a lot of energy from the alternator.

The fig.3.1 shows the three geometrical concepts of the HHO generators which have to be compared among one another to produce the best in terms of operational efficiency, ease of manufacture, ease of mounting, safety and many other significant characteristics.

4. Results of the selection of booster cells and performance

4.1 Selection of booster dry cell

The three booster cells, i.e. the square or rectangular dry cell, octagonal shaped dry cell and the diamond shaped cells were analysed using 12 different criteria and the first concept (square) was selected based on the binary dominance matrix as illustrated in Table 1.

Table 1. Concept selection matrix

Criteria	**Weight**	**Concept Rating**			**Concept Weight**		
		1	**2**	**3**	**1**	**2**	**3**
A. Safety	**11**	9	8	8	99	88	88
B. Cost of material	**9**	10	5	5	90	45	45
D. Ergonomics	**7**	6	8	7	42	56	49
E. Function	**6**	8	8	8	48	48	48
F. Durability	**6**	8	10	9	48	60	54
G. Size	**5**	7	9	9	35	45	45
I. Cost of manufacture	**4**	10	5	6	40	20	24
K. Weight	**1**	5	9	8	5	9	8
L. Ease of manufacture	**1**	9	5	6	9	5	6
Total Score					**416**	**376**	**367**

Fig 4.2 (a) shows the piping system which will be used for circulation of water and hydroxyl gas. The most significant part of the piping system is the bubbler which prevents flashback of the Brown's gas in the system. A tank stores the water to be used for electrolysis. The water is fed into the HHO cell by gravity. The HHO produced by the cell is then forced out by the internal pressure created by the gas as it builds inside the cell. A pipe transports the gas to the bubblers, then leaving the second bubbler to be transported to the air intake manifold of the engine. Fig 4.2 (b) Electrical system for a controlled power supply to the HHO dry cell when the car is stationary and the engine is off, no current flows in the circuit. Switching on the ignition key induces a current in the normally-open relay and it closes.

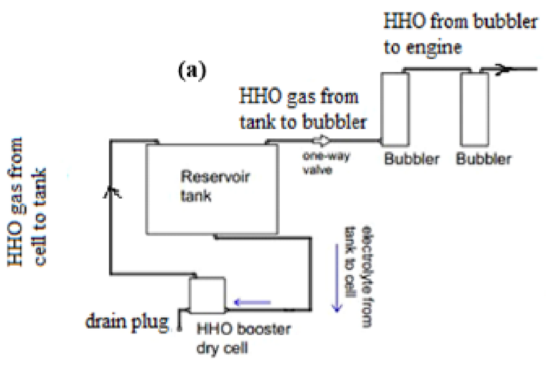

Fig. 4.2. (a) Piping system for circulation of water and HHO gas

Current then flows in the circuit to the electrode plates to produce HHO gas in the booster cell at the same time that the engine is running. Switching off the ignition key stops the engine running whilst simultaneously opening the relay to its normally-open position state. Therefore, the HHO gas will only be produced and provided when it is required by the engine.

4.2 Design of the selected rectangular hydroxyl booster dry cell

The design of the booster cell will cover material selection and dimensioning of plates and gaskets, configuration of electrodes, number of plates required, plate spacing and sizing of fastening components. A voltage of approximately 2V is required between each pair of plates. Water dissolution voltage at 25℃ is 1.23V. Therefore, 2V is aimed for because of voltage that drops in the circuit due to the electrical cables and electrode plates. To achieve an equal voltage across each pair of plates, the series configuration is selected. Electrodes are configured in a series arrangement. Standard car batteries supply 12V. For the proper functionality of the HHO dry cell, 2V is required per water cell which is the space in-between two plates containing the electrolyte.

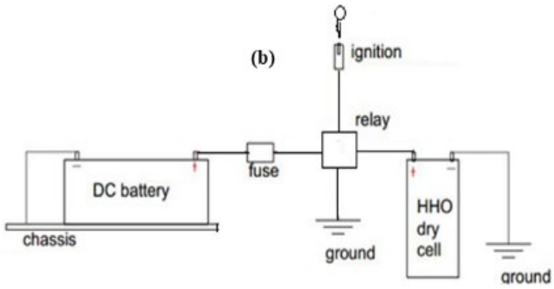

Fig. 4.2. (b) Electrical system connection

The physical parameters of the HHO generator are given in Table 2. These components were then assembled to produce the HHO booster dry cell shown in Fig. 4.3.

The design of the booster cell covered material selection and dimensioning of plates and gaskets, configuration of electrodes, number of plates required, plate spacing and sizing of fastening components. A voltage of approximately 2V was required between each pair of plates. Water dissolution voltage at 25℃ was 1.23V. Therefore, 2V was aimed for because of voltage that dropped in the circuit due to the electrical cables and electrode plates. To achieve an equal voltage across each pair of plates, the series configuration was selected. Electrodes were configured in a series arrangement and standard car batteries supply of 12V. For the proper functionality of the HHO dry cell, 2V was required per water cell which was the space between two plates containing the electrolyte. The physical parameters of the HHO generator are given in Table 2. These components were then assembled to produce the HHO booster dry cell shown in the picture on Fig. 4.3.

Table 2. Parameters of the chosen cell

Item number	Description	Quantity or size/type
1.	Number of water cells required	6
2.	Number of plates required	7
3.	Number of neutral plates	5
4.	Number of gaskets	8
5.	thickness of the gaskets	3
6.	Max current	20A
7.	The water cell area	220mm by 120mm.
8.	Sets of bolts washers and nuts	12
9.	Plate type	steel of grade 316L

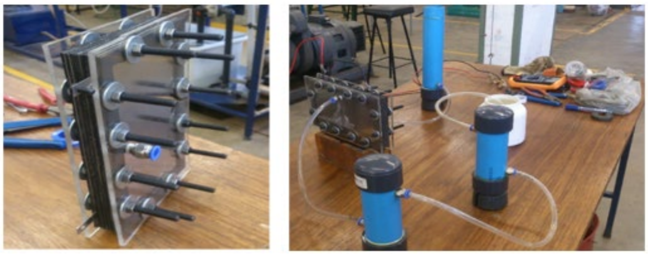

Fig. 4.3. The setup of the HHO generator cell with two bubblers

4.3 The results on the application of a rectangular hydroxyl booster dry cell on an ICE.

The graphs below (Figs. 4.4 and 4.5) show Brake thermal efficiency and fuel economy improvements when gasoline with brown gas is used as fuel compared to pure gasoline. This is due to the high potential power obtained from the HHO gas combustion and better combustion conditions. See Fig. 4.4 and Fig. 4.5 for this fact.

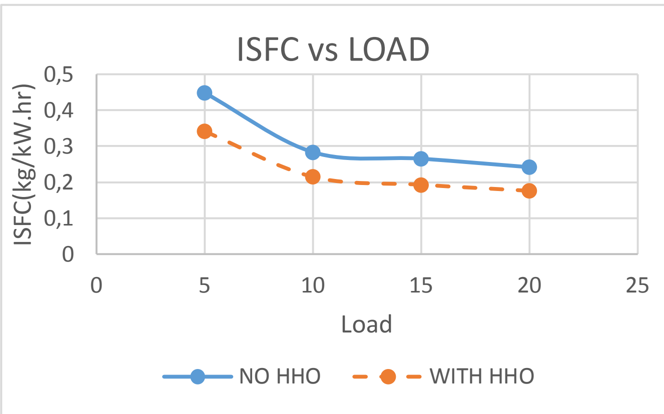

Fig. 4.4 Indicated Specific Fuel Consumption(ISFC) against Load

Discussion and recommendations

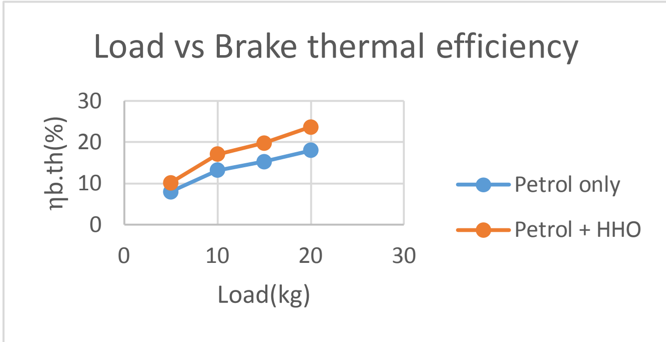

Fig. 4.5 Brake Thermal Efficiency against Load

The factors which influenced the research included maximized HHO production, effectiveness of the cell in lowering global warming causing greenhouse gases (GHGs), manufacturability and the cost implications of the booster cell design. It was vital for this research to be carried out as it brought forth benefits including, cost reduction on fuel expenditure for vehicle owners. This was due to the fact that the HHO booster cell produced hydroxyl gas which initiated a more complete combustion of the gasoline fuel translating into cost savings, reduction of air polluting toxic substances due to the quenching effect of water, reduction of soot, thereby cleaning the engine in the process and also increasing thermal efficiency of ICEs. More of the gasoline was burnt completely due to hydrogen's explosive nature, hence greater power was generated instead of losing it as hot emissions through the exhaust. The flammability property of HHO gas can be manipulated in other related manufacturing processes such as welding, cutting and melting metals. The by-product in all these processes is pure water, which is environmentally friendly. Recent interest has developed in HHO torches, which are powered by HHO gas. As such, it can be envisioned that hydroxyl gas will be relevant in more fields of science and engineering within the near future. The cell material contains chromium which although catalytic is poisonous, further research is needed to minimize its negative effects or substitute it completely.

5. Conclusions

Fossil fuels remain the main source of energy for internal combustion engines. The introduction of hybrid vehicles and electric cars has still not surpassed the gasoline powered and diesel powered engine vehicle as the leading avenue for road transportation. The greenhouse emissions exhausted by the engines consequently lead to global warming and climate change. The hydroxyl booster dry cell can act as interim technology which alleviates the current challenges stemming from fossil fueled engines, at the same time allowing further improvements to be carried out on designing and manufacturing of vehicles which are environmentally friendly. The HHO gas produced by the hydroxyl booster cell initiated a more complete combustion of the gasoline, leading to cleaner vehicle emissions.

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